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PLZT ELECTRO-OPTIC PHOTOGRAPHIC SYSTEM

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Technical Report

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The challenge of this effort was to develop and field a Lead-Lathanium-Zirconium-Titanium (PLZT) Electro-optic enhanced photographic system, for high speed photographic documentation of Thermal Radiation Sources (TRS)/High explosive (H.E.) detonations. Operational design parameters of this system were to have a 6 f-stop dynamic range and pulse response of 100 micro-seconds or less. A prototype PLZT system was designed/fabricated and laboratory tested with a wide variety of dynamic light sources that had substantially different spectral characteristics and radiant output. The prototype system performed satisfactorily for these test series and consequently a semi-hardened unit was fabricated for field use. The fabricated field unit was successfully tested with rocket propellant burns that simulated light intensities within the camera/PLZT systems field of view (FOV). These test results provided the confidence that the system was ready for deployment to a large scale test site. The PLZT photographic system was fielded on Project MISTY PICTURE to record the total TRS burn at the 10 psi (69 Kpa) overpressure environment. Several

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19. ABSTRACT (Continued)

pre-event TRS burns were recorded. These film records were analyzed and electronic adjustments were made to optimize the dynamic range of the PLZT system. The PLZT system was subsequently tested on the MISTY PICTURE event. Film analysis of the event shows that the system performed over its 6 f-stop range, allowing one camera to record the total TRS burn.

SUMMARY

The challenge of this effort was to develop and field a Lead-Lathanium-Zirconium-Titanium (PLZT) Electro-optic enhanced photographic system, for high speed photographic documentation of Thermal Radiation Sources (TRS)/High explosive (H.E.) detonations. Operational design parameters of this system were to have a 6 f-stop dynamic range and pulse response of 100 micro-seconds or less.

A prototype PLZT system was designed/fabricated and laboratory tested with a wide variety of dynamic light sources that had substantially different spectral characteristics and radiant output. The system performed well on these series of tests and provided the background for fabrication of a semi-hardened field unit that operated from battery powered DC power packs.

The completed field unit was tested at Denver Research Institute's field site located southeast of Denver. These tests consisted of igniting solid rocket motor propellant fuel to generate an intense change in light intensity in the camera/PLZT field of view (FOV). Three rocket motor fuel tests were successfully made providing confidence that the system was ready for deployment to a large scale test site.

The PLZT photographic system was transported to the White Sands Missile Range (WSMR) for participation on Defense Nuclear Agency sponsored project MISTY PICTURE. MISTY PICTURE was a large scale H.E. test event, that included TRS units to generate a thermal pulse onto selected targets prior to shock arrival from the detonation. The

particular TRS site selected for the PLZT test was located in an approximate 10 psi overpressure environment. The PLZT photographic FOV encompassed the entire frontal view of the TRS with the target behind the TRS unit. Several test runs were successfully made with the PLZT unit pre-shot to check for analomous behavior of the electronic system. Final adjustments were made and the PLZT was successfully tested on the MISTY PICTURE test event. Analysis of the PLZT photographic film shows that the system performed over its 6 stop range and depicts target motions until obscured by the severe dust laden atmosphere during the negative phase of the overpressure time history.

PREFACE

The author wishes to express his appreciation to Mr. Bob Lynch and Mr. Tim Samaras for their expertise in design, fabrication and testing of the PLZT system. Their cooperation and technical support made this experimental effort a successful endeavor.

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY →	BY →	TO GET
TO GET ←	BY ←	DIVIDE

angstrom	1.000 000 X E -10	meters (m)
atmosphere (normal)	1.013 25 X E +2	kilo pascal (kPa)
bar	1.000 000 X E +2	kilo pascal (kPa)
barn	1.000 000 X E -28	meter^2 (m^2)
British thermal unit (thermochemical)	1.054 350 X E +3	joule (J)
calorie (thermochemical)	4.184 000	joule (J)
cal (thermochemical)/cm^2	4.184 000 X E -2	mega joule/m^2 (MJ/m^2)
curie	3.700 000 X E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 X E -2	radian (rad)
degree Fahrenheit	$t_K = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 X E -19	joule (J)
erg	1.000 000 X E -7	joule (J)
erg/second	1.000 000 X E -7	watt (W)
foot	3.048 000 X E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 X E -3	meter^3 (m^3)
inch	2.540 000 X E -2	meter (m)
jerk	1.000 000 X E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 X E +3	newton (N)
kip/inch^2 (ksi)	6.894 757 X E +3	kilo pascal (kPa)
ktap	1.000 000 X E +2	newton-second/m^2 (N-s/m^2)
micron	1.000 000 X E -6	meter (m)
mil	2.540 000 X E -5	meter (m)
mile (international)	1.609 344 X E +3	meter (m)
ounce	2.834 952 X E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 X E -1	newton-meter (N·m)
pound-force/inch	1.751 268 X E +2	newton/meter (N/m)
pound-force/foot^2	4.788 026 X E -2	kilo pascal (kPa)
pound-force/inch^2 (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 X E -1	kilogram (kg)
pound-mass-foot^2 (moment of inertia)	4.214 011 X E -2	kilogram-meter^2 (kg·m^2)
pound-mass/foot^3	1.601 846 X E +1	kilogram/meter^3 (kg/m^3)
rad (radiation dose absorbed)	1.000 000 X E -2	**Gray (Gy)
roentgen	2.579 760 X E -4	coulomb/kilogram (C/kg)
shake	1.000 000 X E -8	second (s)
slug	1.459 390 X E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 X E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

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SECTION 1

INTRODUCTION

1.1 BACKGROUND.

For many years experimenters have requested high-speed photographic coverage of selected targets subjected, first, to a thermal pulse and then to a shockwave environment such as created with a TRS unit on a H.E. event. The images resulting from photographic coverage provide experimenters with a better understanding of the phenomenological and quantitative nature of the shockwave and the resultant blast loading upon those targets of interest.

From a photographic point of view, TRS experiments are difficult to photograph because illumination levels vary from ambient to 6 f-stops (from a typical daytime illumination level to the 2800-3200° K TRS flame temperature.[1]) Historically, the photographic approach has been to position two to three cameras on each TRS target with each individual camera f-stop set for a particular flame temperature/ambient condition. This has imposed an inordinate amount of equipment and field labor into a single experimental effort. With the advent of the PLZT technology, the redundancy of camera systems to photograph a single target can be substantially reduced.

1.2 OBJECTIVES.

The objective of this program was to develop a low cost PLZT based Electro-optical photographic system to be used in the control of light radiation used in exposing the photographic emulsion in high speed photography for high explosive/TRS events.

To accomplish this objective, the program was divided into three technical tasks as follows:

Task 1 - Design, develop and fabricate a bench-top model PLZT electro-optical photographic system. This task included integration of the PLZT technology into a system comprised of power supplies (DC-DC converters), high speed photodetector/electronics (to servo loop the PLZT) and optical components necessary to implement the system.

Task 2 - Demonstratation of the capabilities of the bench-top model system to variations in light flux and the ability of the system to operate by a servo-loop within the expected operating parameters. The demonstration sources utilized to test the bench-top model in the laboratory consisted of flash bulbs and quartz halogen lamps. It was expected that these light sources would closely simulate the light conditions encountered in the field test events.

Task 3 - After analyzing the results of Task 2, necessary corrections were made, and a semi-hardened field unit was fabricated. This unit was packaged for normal high speed photographic operational requirements. The installed system was to be used in a large scale field test to qualify the desired operating parameters. The system was fielded on a large HE/TRS event, MISTY PICTURE.

SECTION 2

RESULTS

2.1 TASK 1 RESULTS.

The primary effort associated with this task was dedicated to the characterization of the PLZT shutter assembly and to the development of the appropriate electronic control/drive and power supply circuitry.

2.1.1 Shutter Assembly.

Due to the design concept of keeping the PLZT shutter system separate from the camera for ease of installation on various types of high speed cameras, a decision was made to utilize a Motorola 2-inch circular shutter assembly. This 2-inch shutter provides an approximate 1 5/8-inch diameter clear area for insertion into the optical path in front of the lens. Other specifications, as related to the shutter include, a 20 mil nickel composition electrode spacing, type A (quadratic) material type, bonded lens assembly and a 32 percent glass mounted polarizer. This shutter configuration provides transmission characteristics of approximately 14 percent in the on-state and 0.007 percent in the off state. These percentages are averaged across 400-700 nanometers in wavelength; as expected transmission values versus wavelengths are not constant. To maintain reasonable color fidelity on the film emulsion the shutter should be operating at 100 percent of the half wave voltage which would provide color transmission from black to white (first order). Further increases in half wave voltages result in the shutter operating in a color filter mode i.e., in the second order condition.

2.1.2 Shutter Performance Data.

For development of control circuitry, it was necessary to measure the performance of the shutter for applied excitation voltage versus transmission and to characterize the hysteresis curve for the "best fit" over the anticipated operating ranges. Figure 1 depicts the results of applied voltage versus measured transmission. Figure 2 shows the results of circuit performance which is optimized for the "best fit" of the hysteresis curve data from Figure 1, with a tabulation of calculated f-stop errors across a 6 f-stop range. It should be noted, that the expected operating range of the shutter was derived from film records and the DRI letter report "Photographic and Photometric Measurements from BRL Thermal Radiation Simulator, Number Two", (J. Wisotski) 22 Sept. 1986. These records indicated a requirement of an f-stop operating range of 4 to 6 stops. Therefore, the control drive voltage was selected for a maximum of 6 stops from ambient conditions.

2.1.3 IR Suppressors.

During the shutter characterization process, it became obvious that the shutter would pass radiation beyond the film spectral sensivity of approximately 400-700 nanometers. An EG&G Model 585 monochrometer was utilized to profile the radiation passband of the shutter. This profile showed high transmission values to 1.1 microns, which falls within the range of the photo-detector sensitivity curve (see Figure 3) used for the feedback control circuitry. Because of the large amounts of near-IR radiation associated with the TRS/HE test

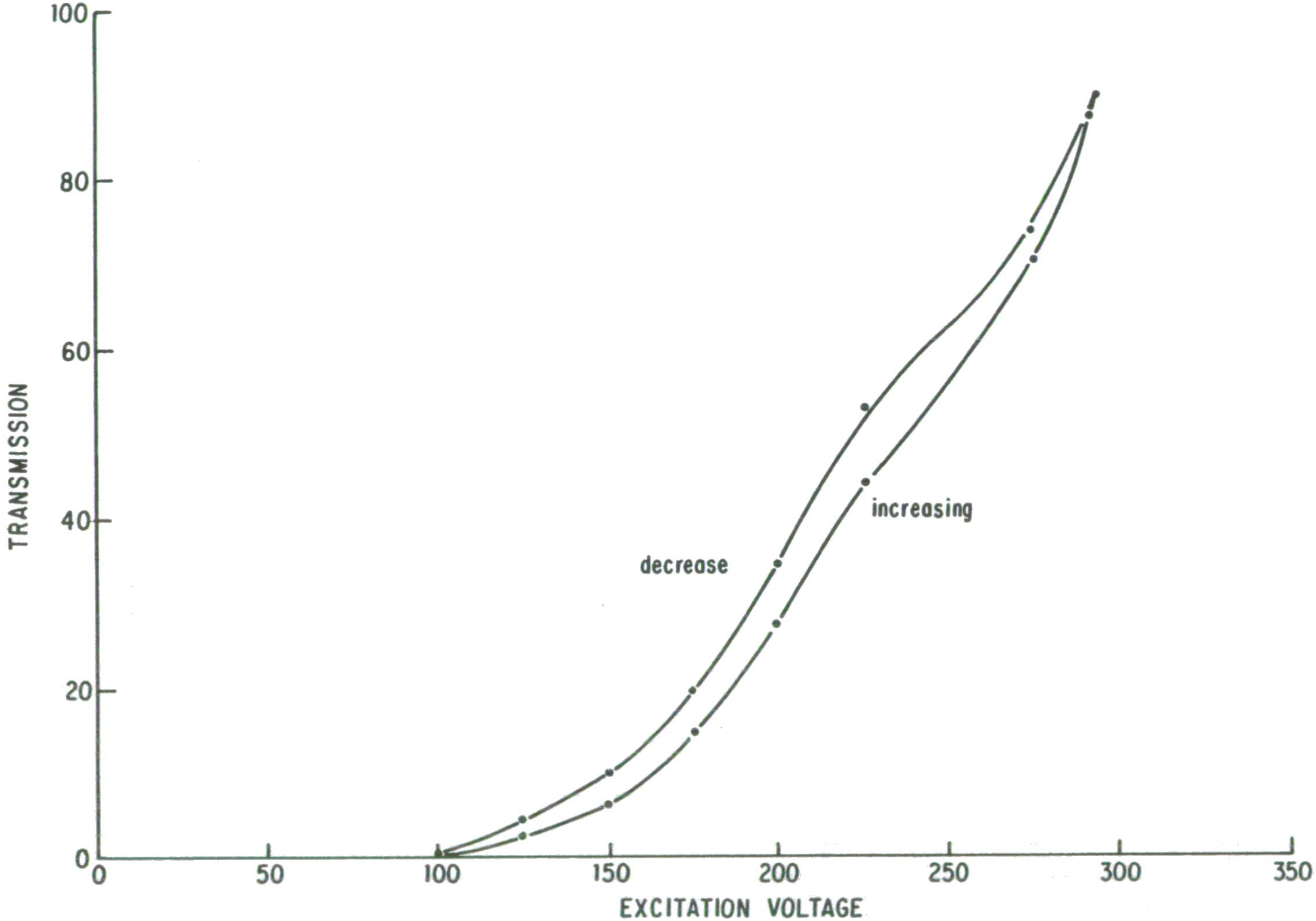
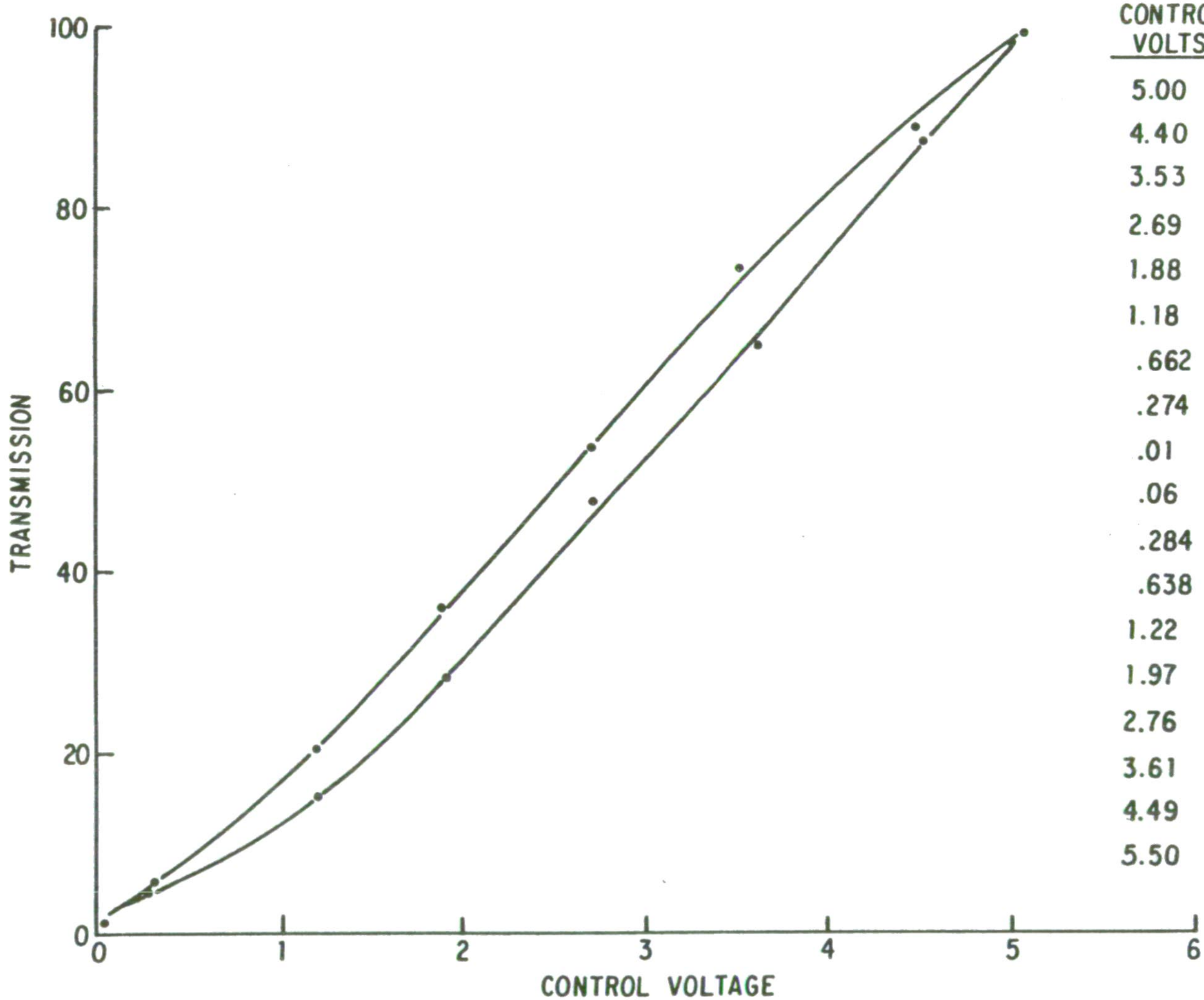


Figure 1. Shutter characteristics.



f-STOP ERROR (6 STOPS)			
CONTROL VOLTS	IN f-STOP	OUT f-STOP	Δ f-STOP
5.00	0	0	0
4.40	.2	.1	.1
3.53	.5	.4	.1
2.69	.9	.9	0
1.88	1.4	1.5	.1
1.18	2.1	2.3	.2
.662	3.0	3.3	.3
.274	4.2	4.6	.4
.01	–	6.0	–
.06	6.4	6.0	.4
.284	4.1	5.1	1.0
.638	3.0	3.8	.8
1.22	2.0	2.7	.7
1.97	1.3	1.8	.5
2.76	.9	1.2	.7
3.61	.5	.6	.1
4.49	.2	.2	.1
5.50	0	0	0

Figure 2. Optimized circuit/system performance.

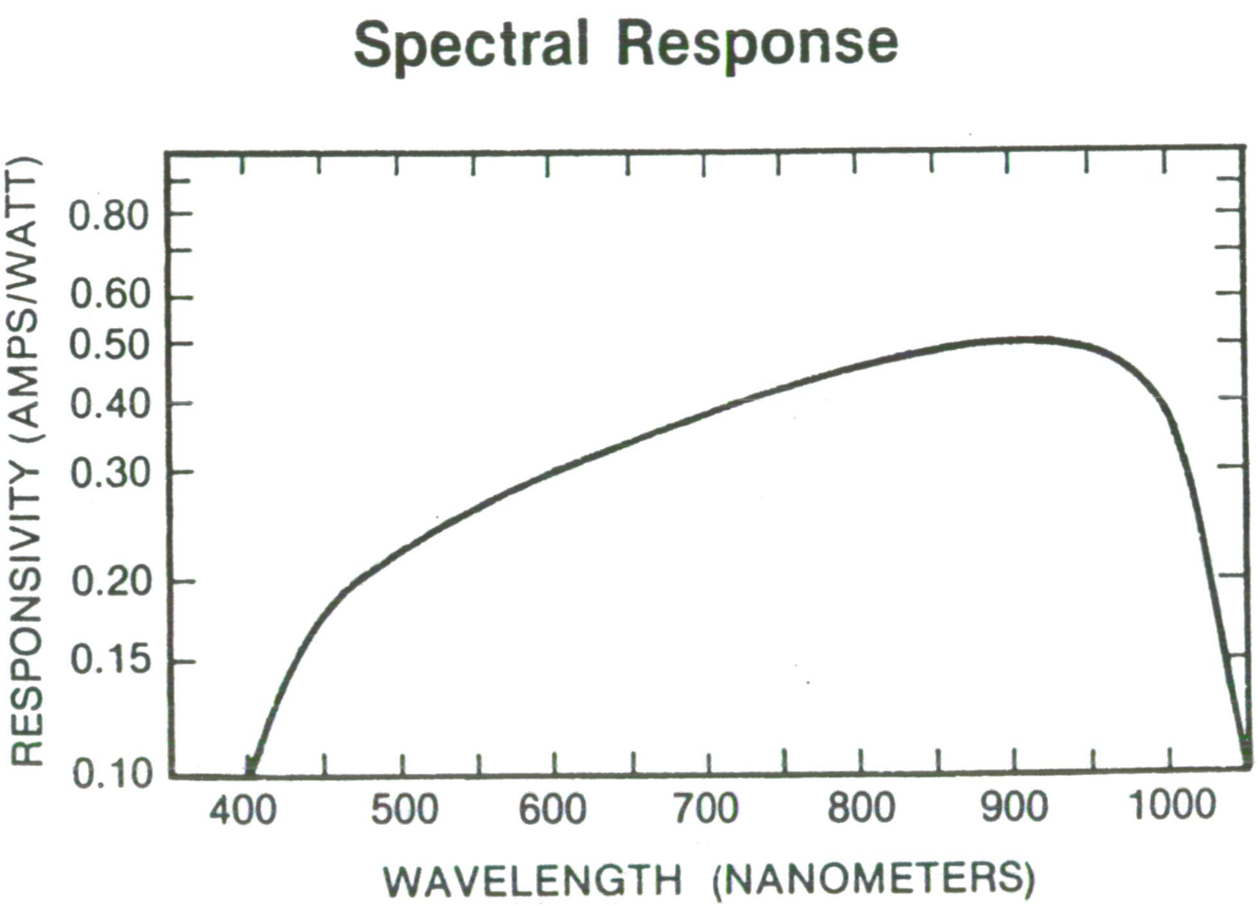
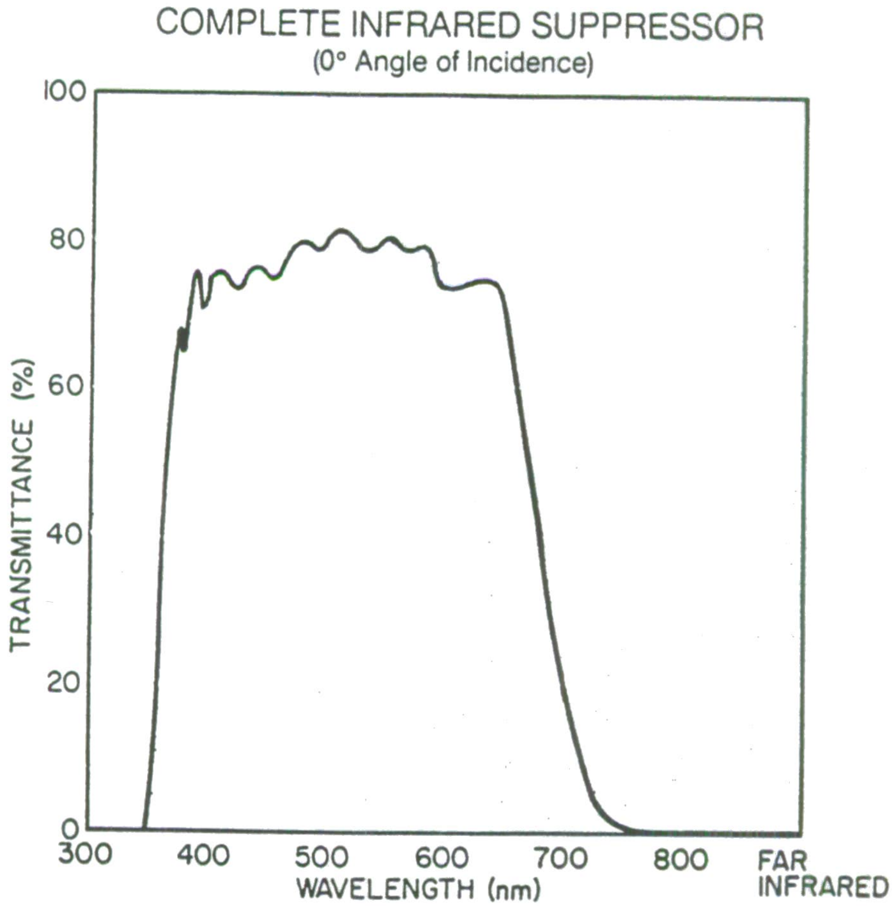


Figure 3. Photodiode spectral response.

events, it was decided to limit the detector radiation to the same spectral values as the film (400-700 nanometers). To define the spectral passband within the limits of the detector an infrared suppressor was selected. Figure 4 depicts the suppressor passband of 350-700 nanometers. In addition, this IR suppressor provides thermal protection (from combined reflection and absorption) for the optical components comprising the PLZT system. Figure 5 depicts the optical arrangement. Previous TRS photographic experiences have demonstrated that dark objects (such as wratten filters) cannot withstand the fluence (CAL/CM^2) inputs for normal camera locations. This thermal protection becomes a requirement for those cameras positioned in close proximity to a TRS event and when the shutter is in its least transmissive mode of operation.

2.1.4 Electronic Control and Drive Circuitry.

The greatest amount of effort for this task has been expended on the control and drive electronics that provide the operating conditions of the shutter. Actually, three separate circuit configurations have been bread-boarded and evaluated as to switching speed and control stability. These circuit configurations have been modeled to the portable (battery operated) requirements and also to the separate light measuring reference for exposure control rather than an intergrated "behind the shutter" servo lock technique. This separate light control for a "stand alone" PLZT system requires that the field of views (FOV's) of the camera film plane and the control light detector be the same. The control and drive electronics designs were derived based upon these system requirements. Figure 6 depicts the



TRANSMITTANCE:
70% average from 400nm to 650nm.

REJECTION:
1.0 x 10^{-3} from 800nm through complete infrared.

Figure 4. IR suppressor passband.

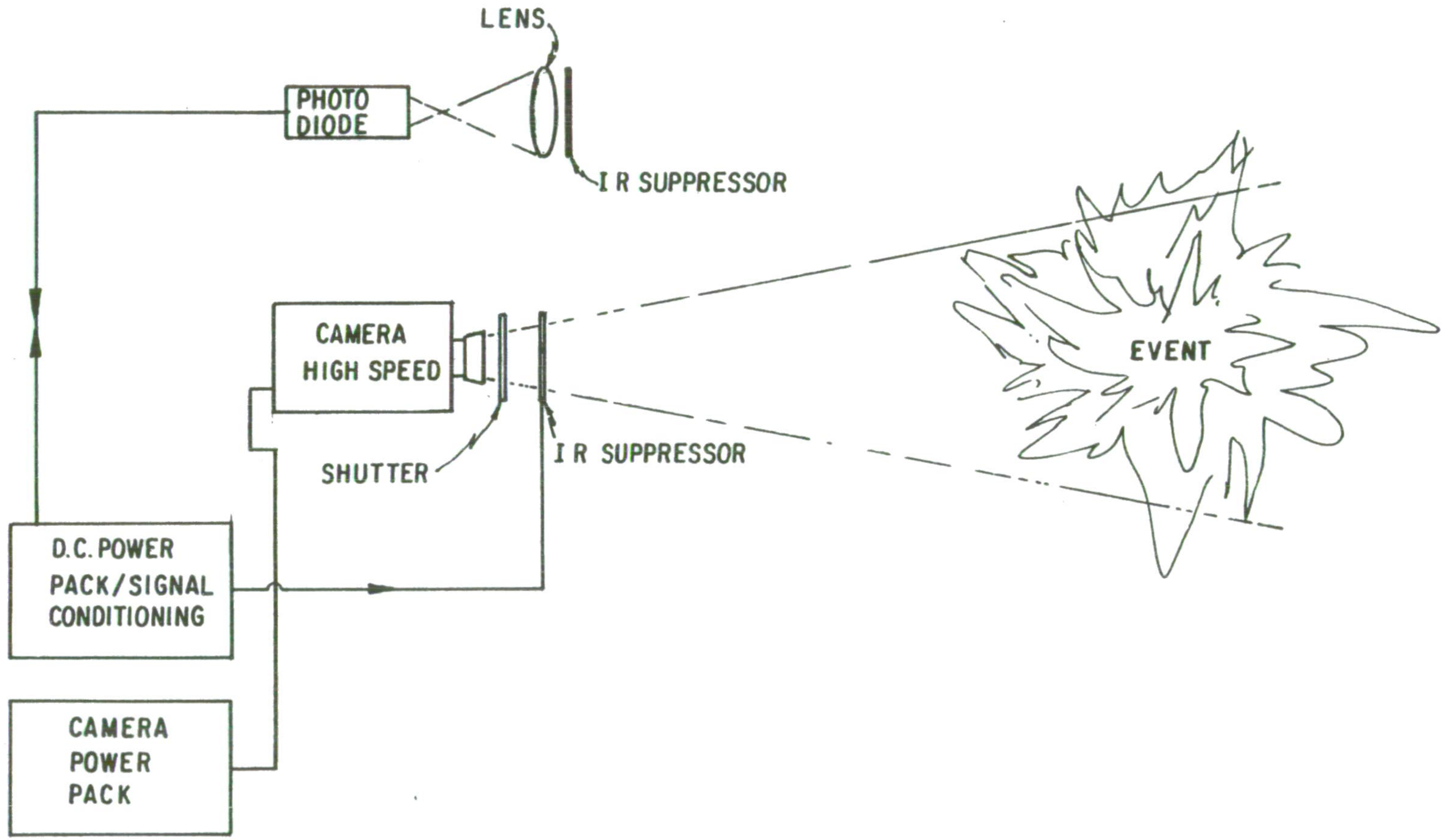


Figure 5. IR suppressors relationship to PLZT system.

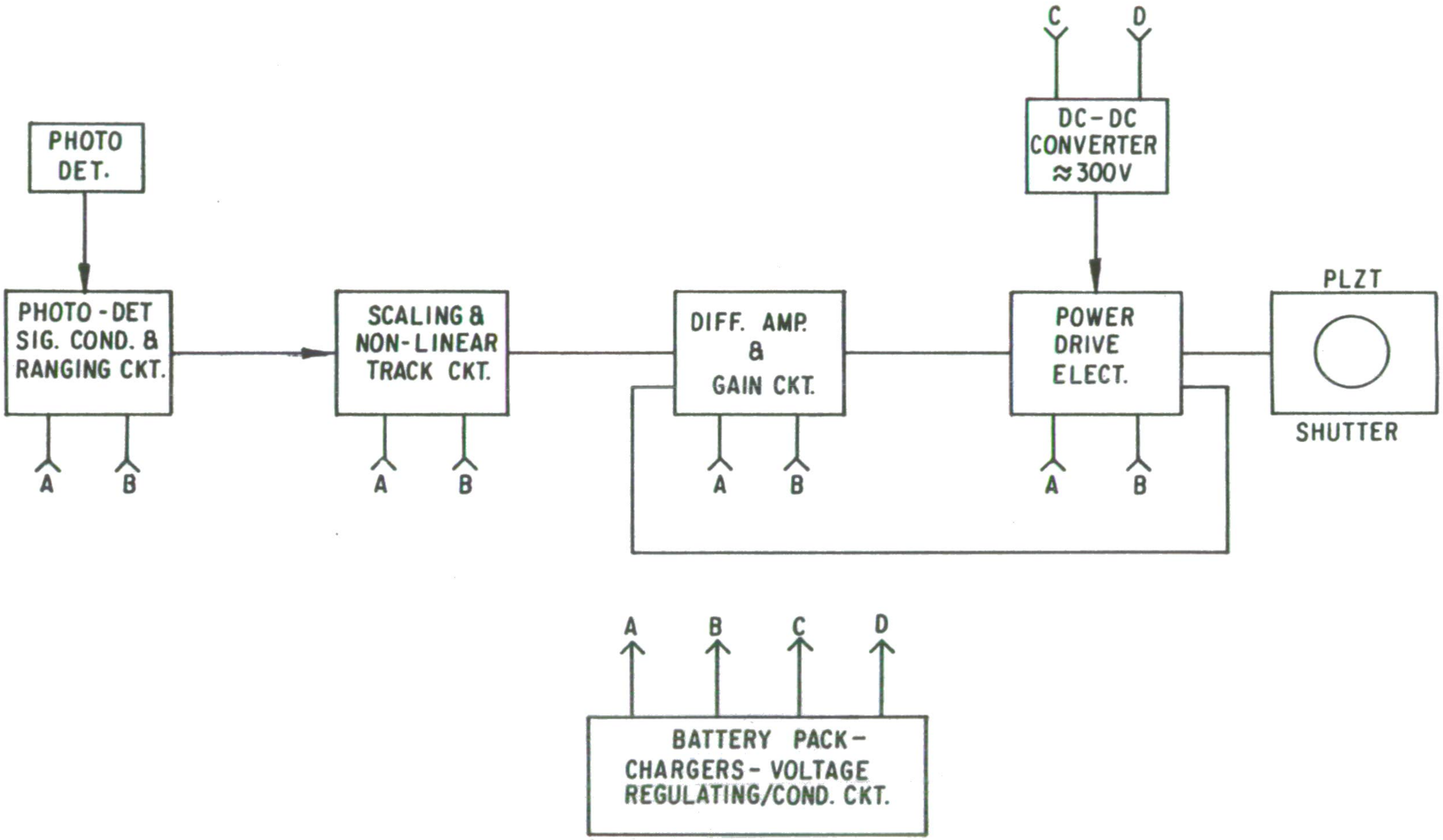


Figure 6. Electronic block diagram.

block diagram of the electronic drive and control system selected on the basis of reasonable switching transitions and good control stability within the control loop lock range. Preliminary measurements of light radiation switching speeds are 30 microsecond "on to off" and 100 micro-second "off to on" (-.25 f-stop).

2.2 TASK 2 RESULTS.

Task 2 resulted in the charaterization of the fabricated PLZT system to variations in light flux levels and determinations of its ability to servo loop within its dynamic operating range.

2.2.1 Laboratory Setup of the PLZT System.

Characterization of the completed PLZT system to differing light sources and illumination levels requires that a uniform target area be presented to the lens's field of view (FOV). To accomplish this task, a target area was fabricated using neutral colors and erected 12 feet (3.66m) from the PLZT system. For this test series the PLZT was installed on a DBM high speed camera. The PLZT detection system was installed on the top of the camera, with its lens (the same focal length as the camera's) along the optical axis of the camera. To preclude paralax problems arising from the different vertical geometry of the two lenses, a minimum distance of 12 feet (3.66m) from the target was selected. This 12-foot (3.66m) distance also coincided with a distance that would provide adequate illumination levels to fully exercise the PLZT system. One-thousand-watt Quartz Halogen photographic lamps were utilized in all test scenarios to provide background illumination levels that are typical for outdoor conditions of a bright, cloudless day.

These background illumination lamps were positioned approximately four feet (1.22m) from the target area.

During the early phase of testing, there was a concern that the high index of refraction of the PLZT shutter would create problems with off-axis light radiation. Considerable effort was expended testing this potential problem area. It was determined that it was helpful to aperture the outer perimeter of the shutter, thereby excluding edge effects and potential reflection problems. Also, the cavity behind the PLZT assembly was coated with a dull black lacquer to prevent reflections from the bright metal surfaces that could possibly be refracted into the optical path. These procedures appear to work very well, as the following discussion of the experimental data shows.

2.2.2 Dynamic Laboratory Illumination Tests.

An FF-33 lamp was used to provide a two-second illumination level that exceeds 10^4 lumens at a color temperature of 3800°K (nearly the estimated temperature of a TRS system). To determine the effectiveness of the PLZT system to this light source, the signal output of the detector (used in the servo loop) was recorded, as was the output of a similar detector focused at the film plane of the camera. The difference in detector signal was calculated for the input F-stop range and the film plane detector signals were calculated to determine the change in F-stop. In a perfect system the film plane detector would remain constant; however, due to shutter histories, circuit non-linearities, circuit response times, source spectral response and repeatability errors, the culmination of errors may be one F-stop (original design goal of Task 1). Laboratory tests have confirmed that

the control system is capable of maintaining the shutter transmission to one F-stop. Figure 7 depicts the system exposed to an FF-33 photo flood flash lamp. The top trace is the light detector output while the bottom trace is the light at the film plane. These traces show that the illumination level within the lens's FOV was abruptly changed 5.3 stops and after accounting for the time constant of the control circuit, the film plane light was controlled to less than 0.5 F-stop. Figure 8 shows the system response to a Quartz Halogen lamp illumination input level of 1.34 stops. The bottom trace shows that system response controlled the light impinging on the film plane to less than 0.2 F-stop. Figure 9 depicts the PLZT system exposed to an electronic strobe. This strobe was operated in a manual mode to provide more than two milli-seconds of light (top trace). After the initial delay (an expected 120 micro-seconds), the control system held the film plane illumination level to less than 0.7 F-stop throughout the remaining light pulse.

2.2.3 PLZT Field Tests.

After successful laboratory testing of the PLZT system, field tests were designed employing rocket propellant for a dynamic light source. Three blocks of solid rocket propellant 1 1/2 inches thick and 8 inches square were used. The test configuration is illustrated in Figure 10. All field tests were conducted at the DRI High Explosive Test Facility. The propellant was positioned in a steel channel to shield as much direct radiation as possible from the camera system. It was intended that this technique would provide "front" lighting for selected neutral targets in the lens system's FOV. However, during this test a large amount of the rocket material jetted (or plumed) across the target area

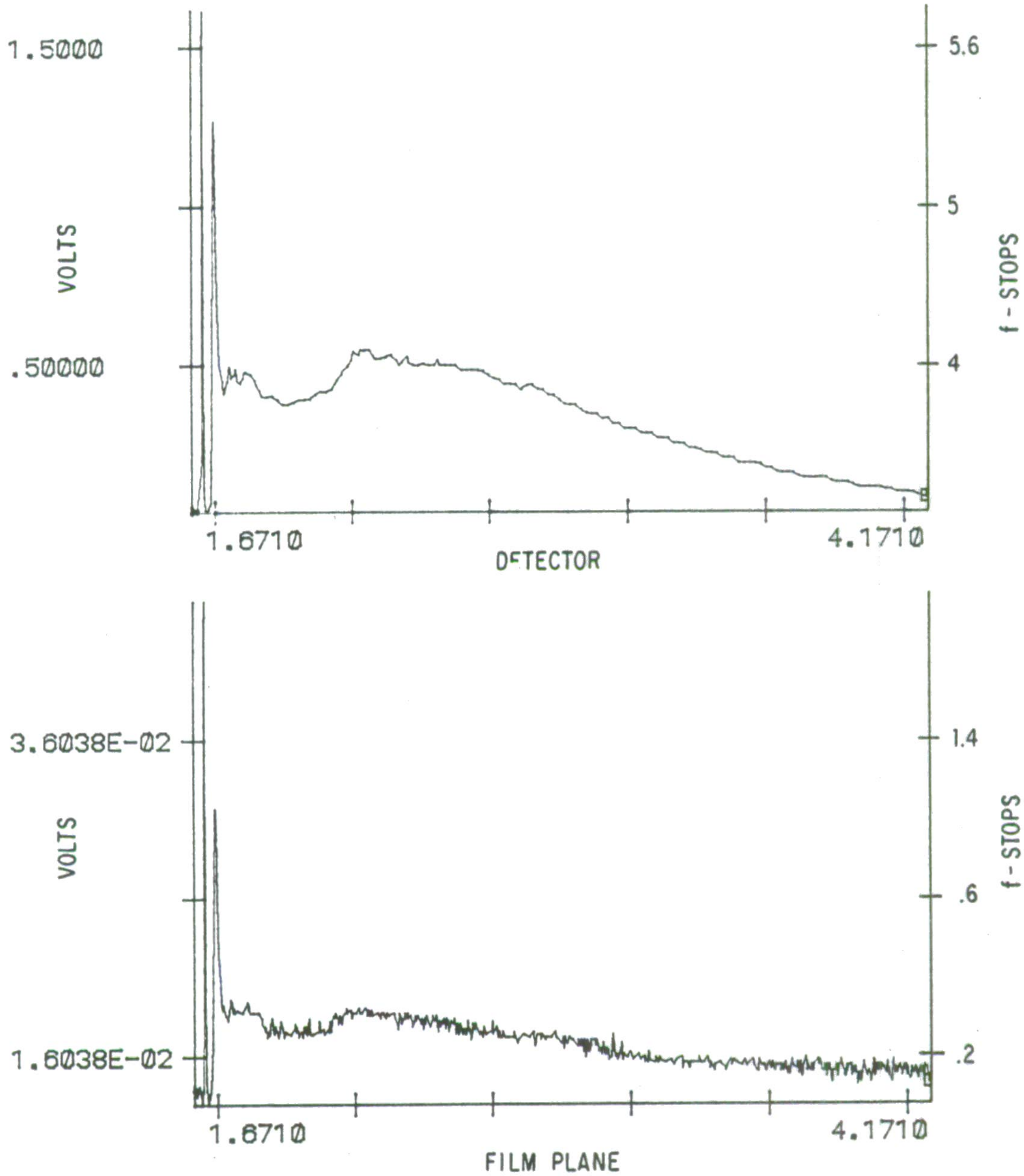


Figure 7. FF33 Photoflood flash lamp control test.

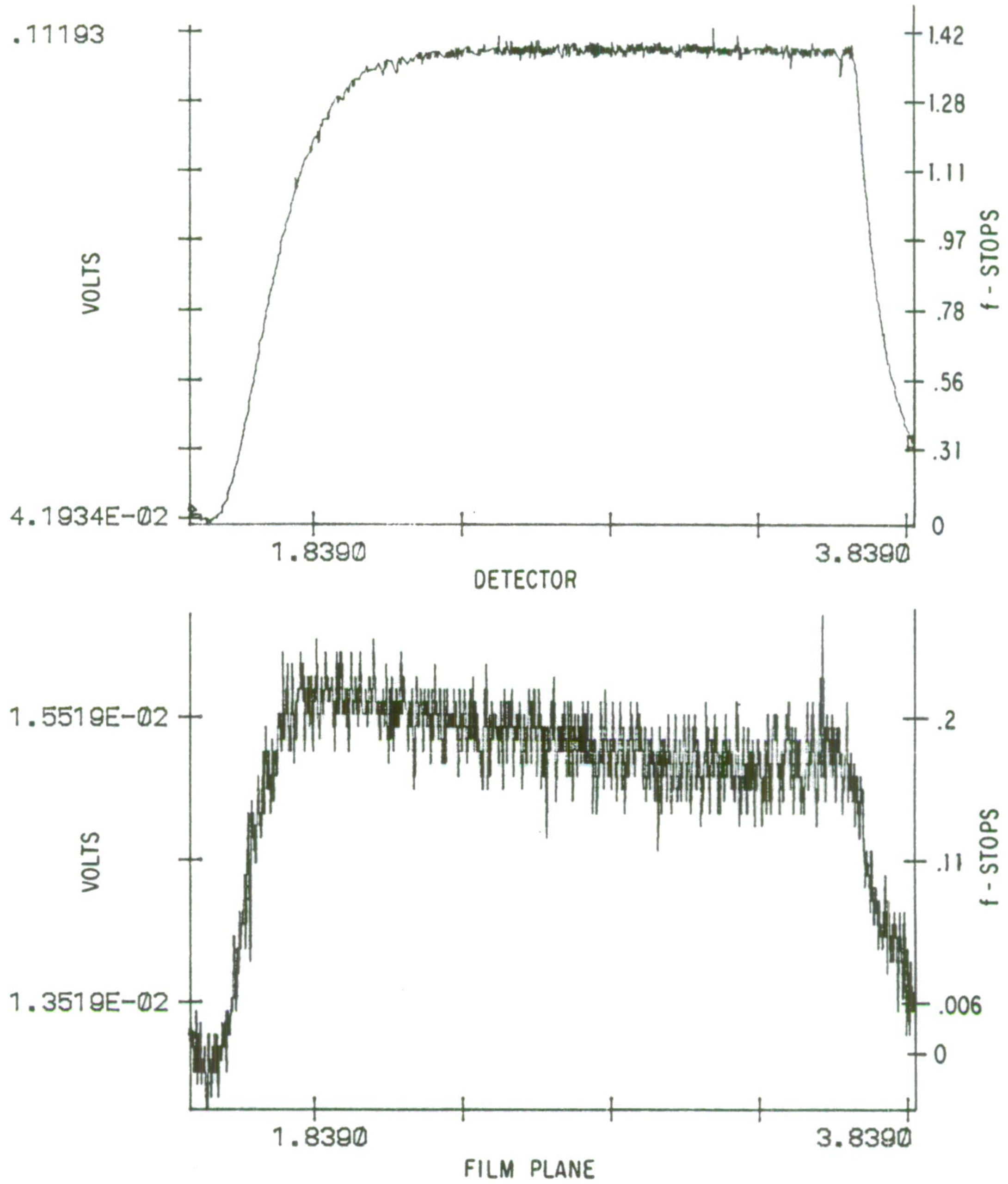


Figure 8. Quartz halogen control test.

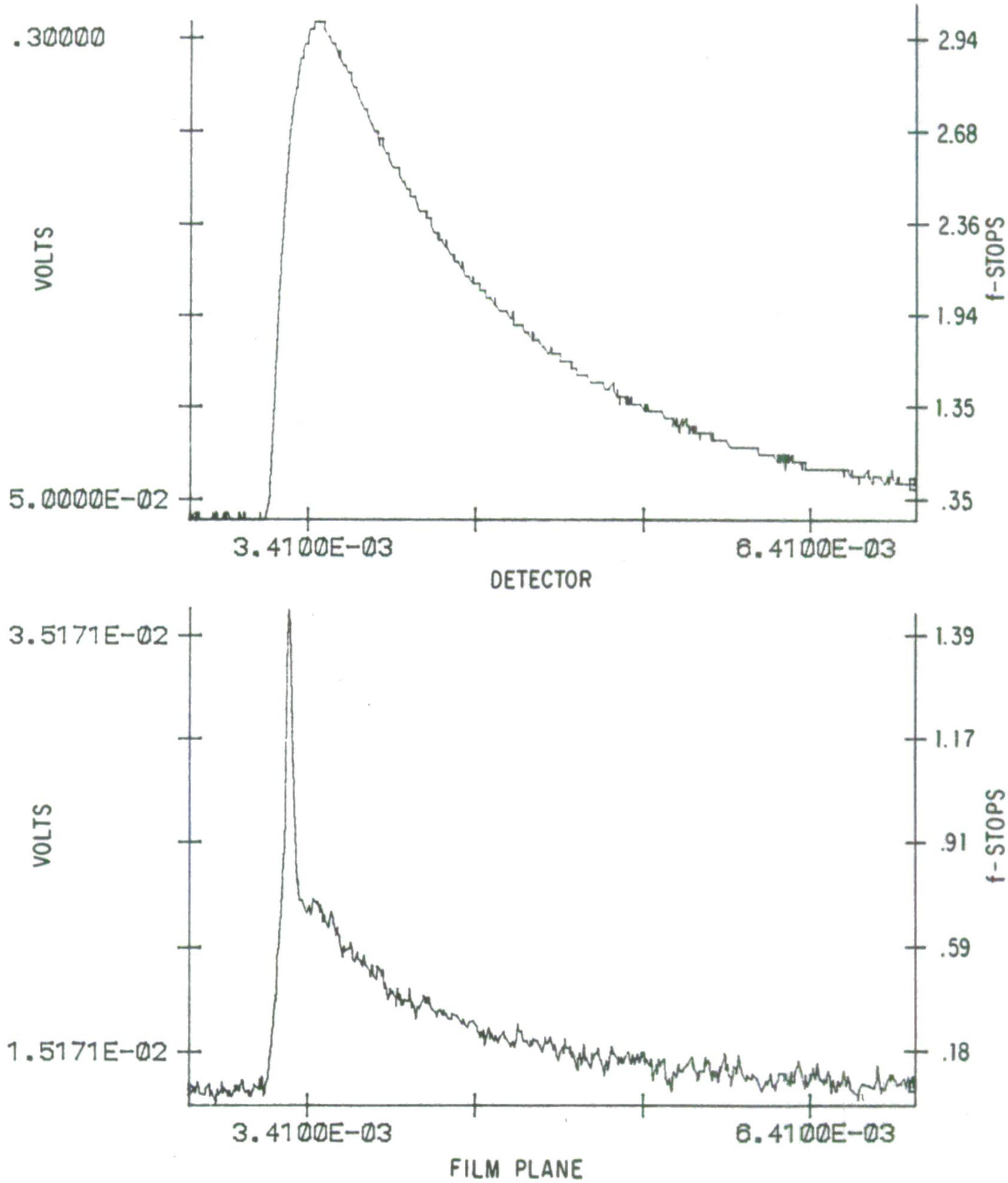


Figure 9. Electronic strobe control test.

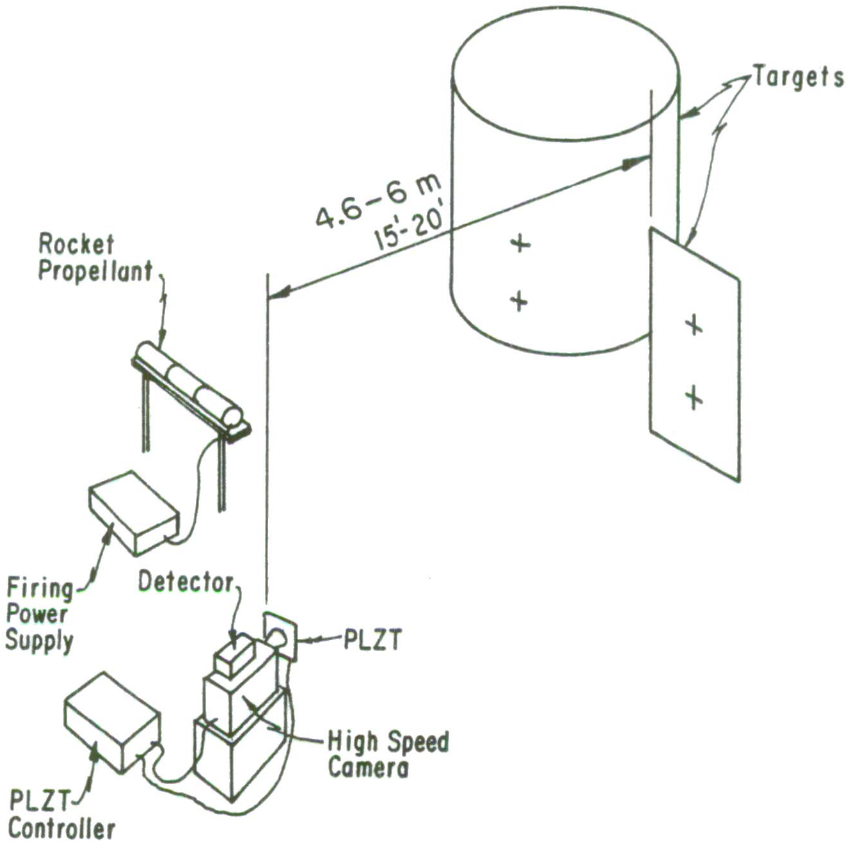


Figure 10. Rocket propellant test setup.

FOV's, creating a diffused looking picture from the copious quantities of white smoke generated during the burn. Figure 11 shows the detector output during the propellant burn and indicates a three F-stop increase in light in the camera's FOV. Figure 12 is a "pre-event" picture, while the rocket plume event is shown in Figure 13. The rocket plume picture is approximately seven seconds into the run. These photographs demonstrate (within processing limitations) nearly the same averaged film density. Note the darkened areas of the stairwell and target on the left edge of the film demonstrating the decrease in the effective aperture of the camera system. Several other tests were conducted at the field site with differing rocket propellant geometries, and these records also indicated that the film density is proportional to the averaged intensity within the PLZT photo-detectors's FOV.

From this photographic evidence it can be concluded that the film records correlate well with the electronic instrumentation utilized in the laboratory for the tested dynamic light sources.

2.3 TASK 3 RESULTS.

Task 3 required analyzing the results of Task 2 (particularly the field test data) and fabrication of the semi-hardened PLZT field unit. This system was then packaged for normal high speed photographic operational requirements.

In the second week of April 1987 the completed PLZT system was ground transported to the WSMR for inclusion on the H.E. test event MISTY PICTURE.

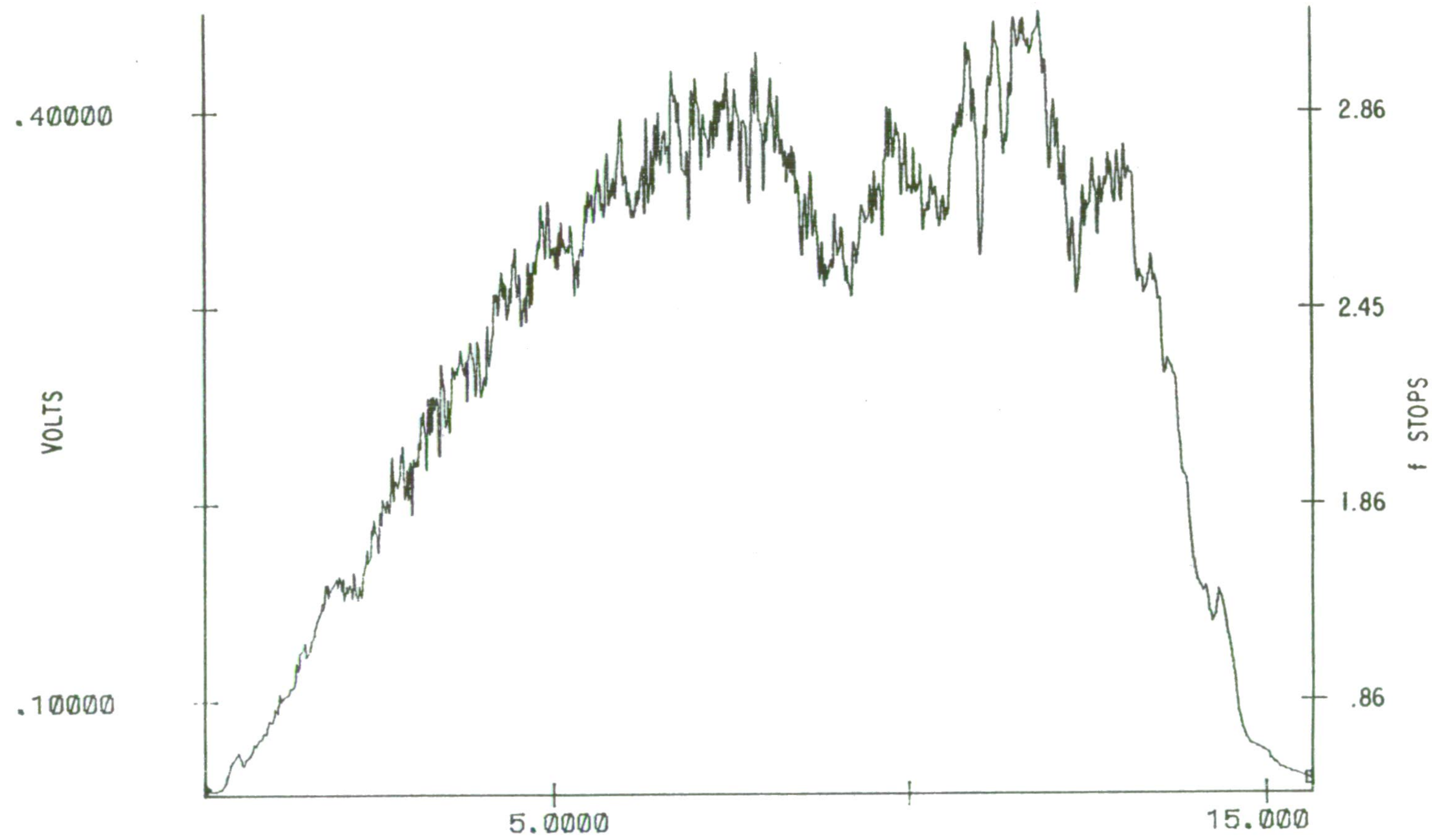


Figure 11. Rocket propellant test (detector output).

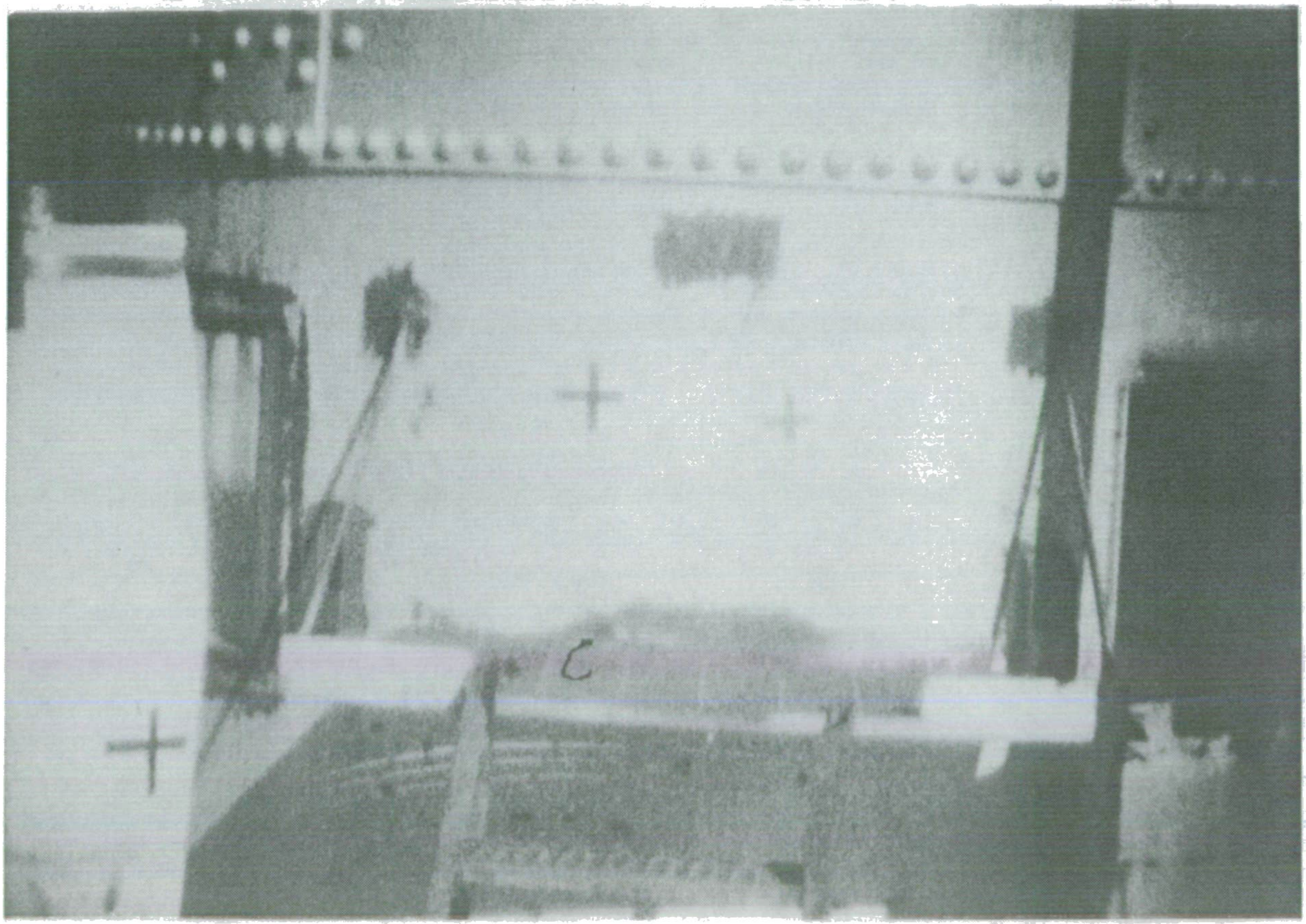


Figure 12. Pre-event picture.

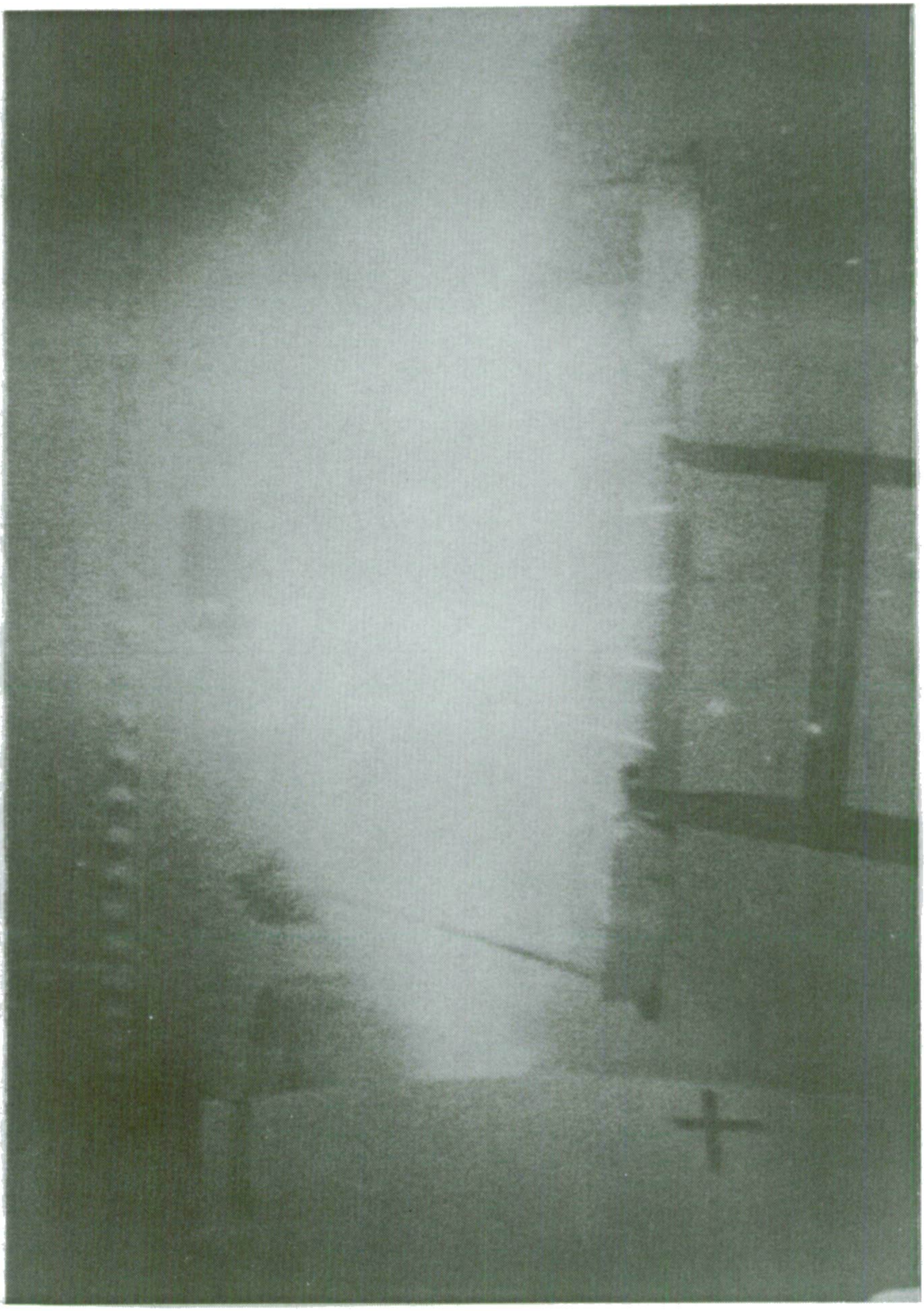


Figure 13. Rocket propellant exposure.

2.3.1 PLZT Location Field Installation.

TRS "A", located in an expected 10 psi (69 kpa) overpressure region, was selected for the installation of the PLZT system (exp. #9005). Figure 14 shows the field site layout. The location of the PLZT camera mount was approximately 80 feet (24.4m) in front (toward the H. E. charge) of the TRS pit. This position, utilizing 25mm lenses (for camera and detector circuit), provided a full view of the entire TRS pit and the target, located directly behind the burners. The PLZT system was mounted in a typical steel camera housing (WSMR Box #58, 8-inches (203.2mm) high x 16.25 inches (412.75mm) deep x 14.25 inches (362mm) across and 0.25 inches (6.35mm) thick walls) perched on top of a 6-inch (152.4mm) diameter steel pipe mounted and reinforced into a concrete pad. The steel camera box was modified for this experimental effort by the removal of the 4-inch 101.6mm) round lens view port and the fabrication of a vertical rectangular view port, measuring 8-inches (203.2mm) high by 4.5-inches (114.3mm) across. This new view port, included sun/blast protection sides, extending 4-inches (101.6mm) around the 4.5 (114.3)x 8-inch (203.2mm) opening away from the housing. Further blast protection of the PLZT system was provided by the installation of 1-inch (25.4mm) thick, high density foam rubber, throughout the interior of the shelter. The camera was installed onto the floor of the camera shelter by "shock isolation washers" on each side of an aluminum plate that sandwiched onto Sorbothane^{R} shock isolation material. This dual mounting system had the desired rigidity, but still allowed the camera to transition slightly under the high acceleration levels inherent upon shockwave arrival, to prevent

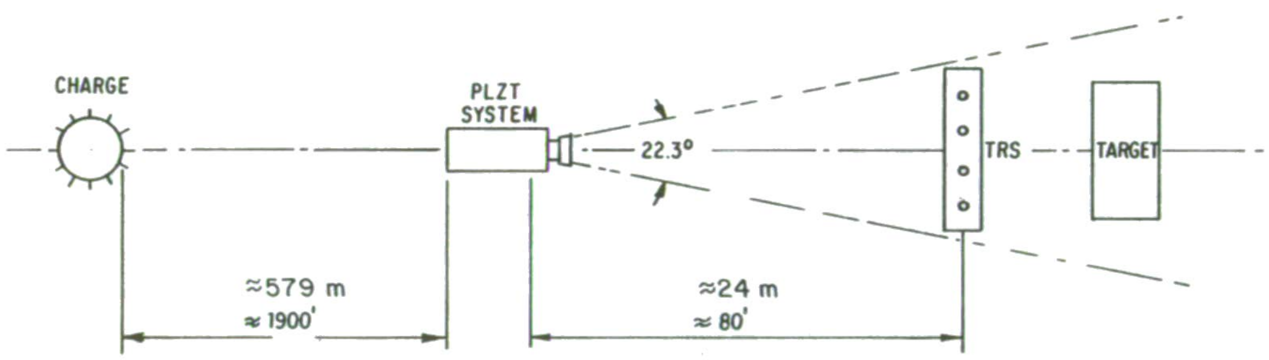


Figure 14. PLZT MISTY PICTURE top view layout (exp. #9005).

catastrophic failure of the PLZT/camera unit. Directly adjacent to the 6-inch (152.4mm) steel pipe, a plywood box was inserted into the ground approximately 18 inches, (457.2mm) to provide protection for the electronic systems from the thermal and blast properties during the test event.

2.3.2 PLZT Timing.

Timing signals required for the PLZT system were generated by the T&F van and were interfaced via field wire from the relay junction box into the buried electronic enclosure. For the pre-event and event film runs, a T-5 second start signal was selected. This allowed ample time for the electronic "run-up" and still allowed the camera system to utilize 125 foot (38.1m) film loads to fully document the pre-event and event TRS and shockwave phenomenon.

2.3.3 Pre-Event Testing.

Several pre-event TRS burns were photographically recorded to ascertain the operating characteristics of the PLZT under field conditions. The first test was a "cold" (TRS was not ignited) TRS run to check for ambient light conditions. This run was somewhat flawed by an inadvertent setting of the iris in front of the shutter assembly resulting in a circular exposure on the film. The iris was re-adjusted prior to the second "hot" run and the resulting film showed that the dynamic range of the shutter assembly was exceeded for the maximum flame temperature the TRS achieved. The electronic drive was re-adjusted and lens f-stop values were subsequently corrected for the actual test event.

2.3.4 Misty Picture Event.

The PLZT camera system was viewed, focused and loaded on the afternoon of May 13th. Final trigger and arming procedures were implemented at 0530 hours for a 1000 hrs. detonation on May 14th.

Following the test event, (during phase III re-entry procedures) the PLZT was examined and film removed from the camera. All visual observations indicated that the PLZT system survived the 10 psi environment without electrical or mechanical damage.

2.3.5 Film Analysis.

The film was processed in a commercial laboratory located in Denver. The results of the film were very good throughout the TRS burn; however, due to the ambient light level (cloudy skies) and the electronic settings to maximize the dynamic range of the system, the pre-burn data appeared to be underexposed by 1 stop. The developed original film positive was used to generate an answer print. This answer print brought out a better lighting condition for the pre-event (ambient light) exposure while maintaining the TRS event exposure. Film analysis shows that the TRS unit did not shut down as expected before shock arrival, therefore when the shockwave interceeded upon the TRS, it appeared to displace the burning plume into the target creating some surface burning of the target. Figure 15 depicts pre-shock arrival. Figure 16 shows a mid burn picture, Figure 17 is a frame at shockwave arrival time and Figure 18 the post shock/start of negative phase time period. As expected, when the negative phase of the shock front occurred, it generated so much dust laden air into the camera FOV that

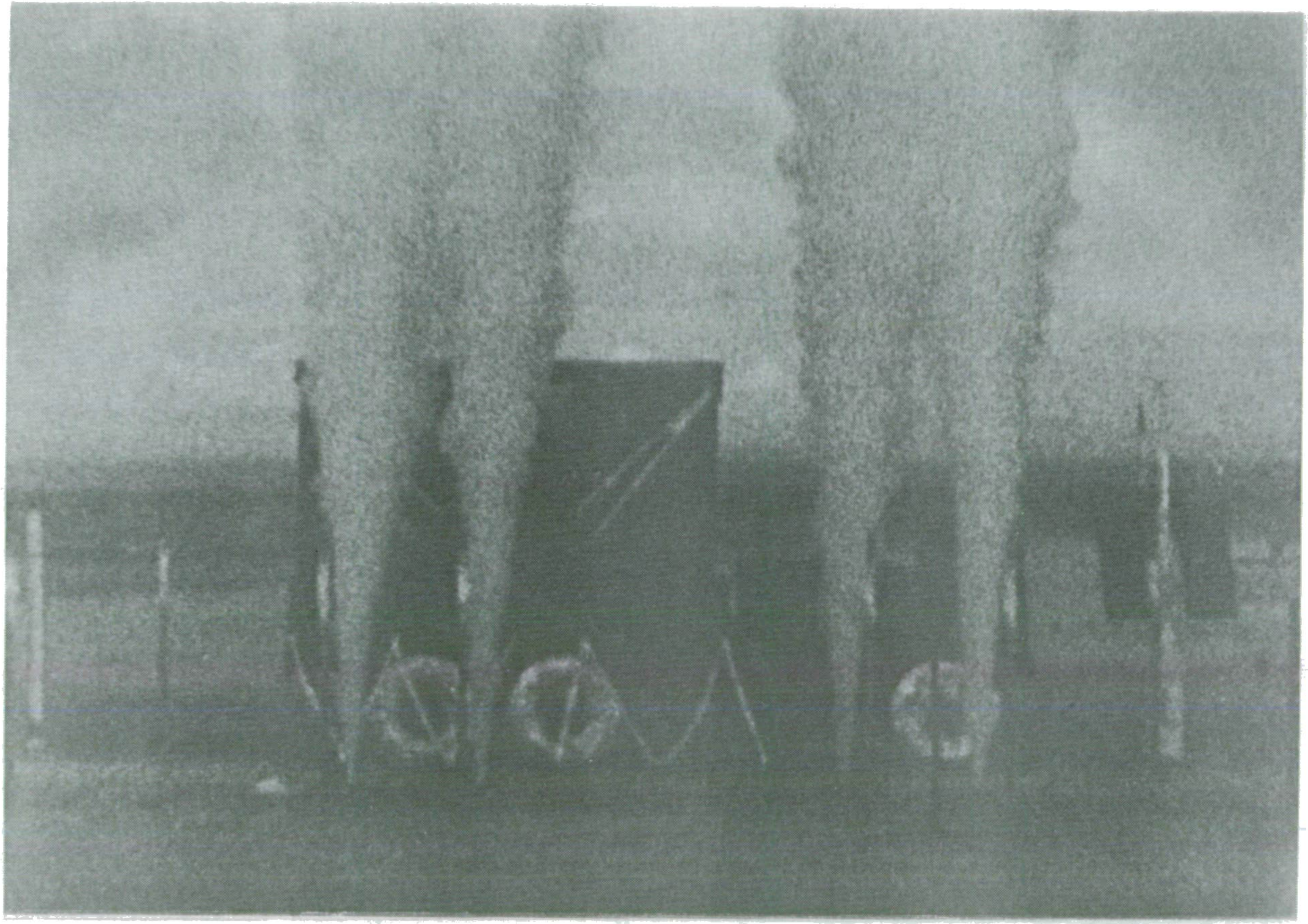


Figure 15. TRS pre-ignition pre-shock arrival picture.

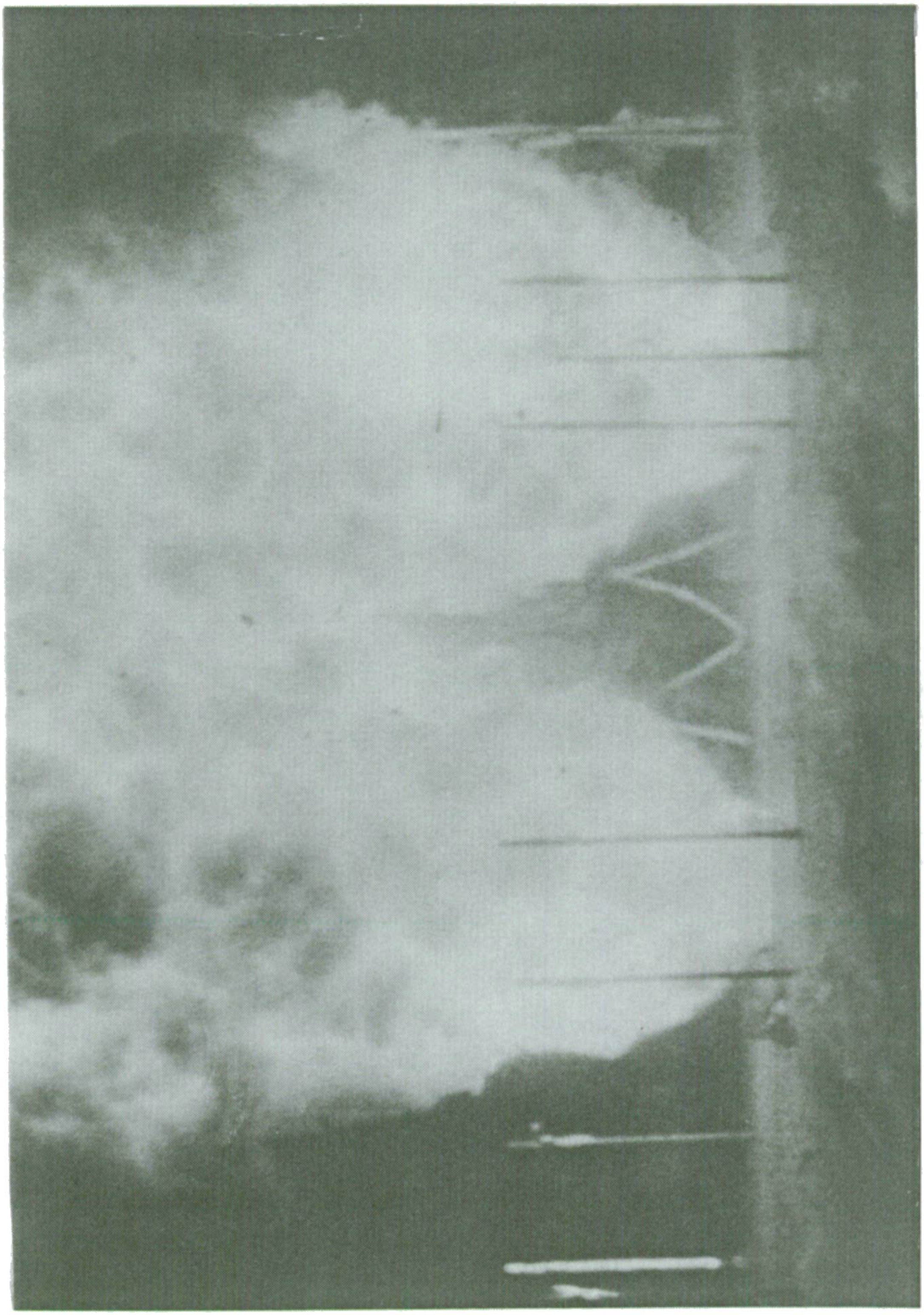


Figure 16. TRS-mid burn picture.

Figure 17. Shock arrival upon target.

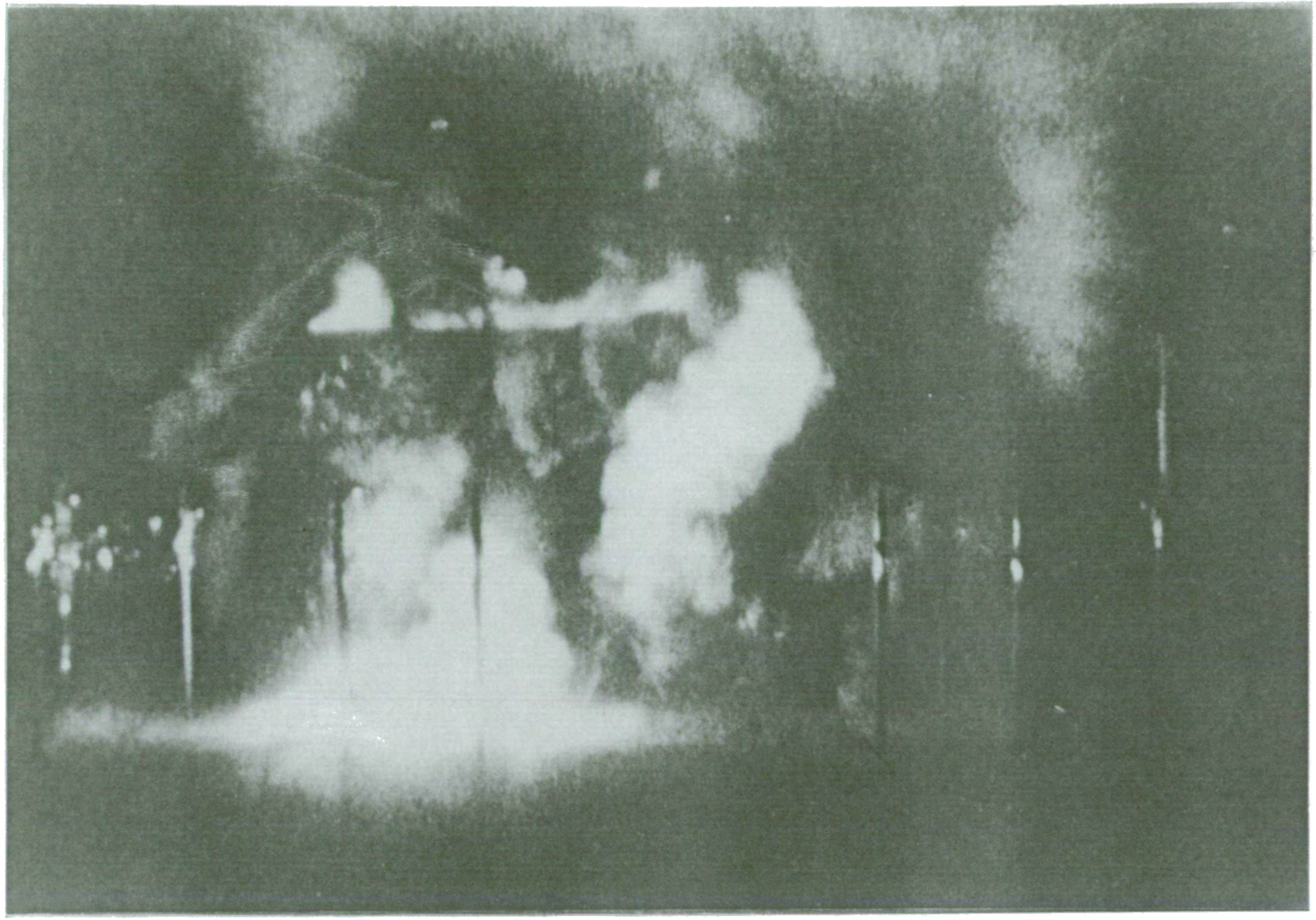


Figure 18. Post shock/start of negative phase.

it totally obliterated the TRS site so further photo-documentation was impossible.

SECTION 3

DISCUSSION

3.1 OVERVIEW.

The PLZT system performed as designed for the TRS experiment on the MISTY PICTURE test event. The film records show that the electronic control system could adequately control the PLZT shutter automatically over a 6 f-stop change in light intensity. This proof-of-concept test provides promise for expanding the dynamic range of photo-instrumentation recording media, for lowering data acquisition costs and for providing a quantum jump in quality data acquisition procedures.

3.1.1 Design Philosophy.

Due to our early design philosophy, based upon experimental work performed at the BRL Thermal Radiation Simulator, it had been expected that the maximum f-stop requirement of the PLZT system was to be 5 to 6. However, based upon the experimental work accomplished at the MISTY PICTURE Event it appears that the dynamic range should be extended for TRS documentation by at least 2 more stops. The reason for this assumption is that it appears that the TRS was burning slightly hotter than the BRL source and also because of the uncertainty of pre-shot ambient light conditions. Also, without the extended range, and with anticipated increases in TRS performance, it may require limitations in PLZT operating parameters.

3.1.2 Future Needs.

Toward the end of the Task 2 development phase, after characterization of the PLZT shutter, an improved optical and servo

tracking procedure was discovered. However, due to funding and time constraints this system could not be explored for an enhanced version of the PLZT for the MISTY PICTURE Event. Basically, the improved PLZT version would increase the dynamic operating range from approximately 7 stops (current model) to nearly 14 stops (new version). Figures 19 and 20 depict the change in layout for the current and new version. The 14 f-stop operating range would provide for a 2 f-stop latitude in the pre-event (ambient light) condition and allow for an additional 12 f-stops during any anticipated TRS or H.E. test event. Additionally, the control/drive system would be redesigned to accommodate the extended range version of the PLZT. The resulting change in the electronic system would negate current problems with signal/noise ratios in the servo detector and provide an enhanced dynamic transition capability.

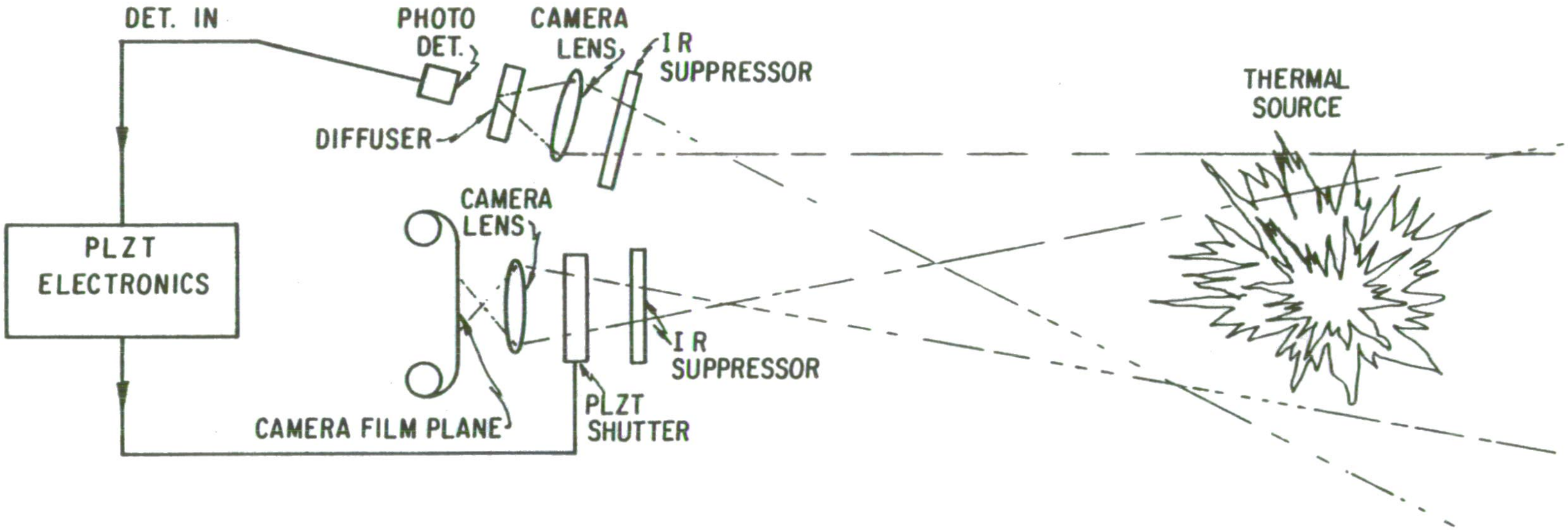


Figure 19. Current PLZT system.

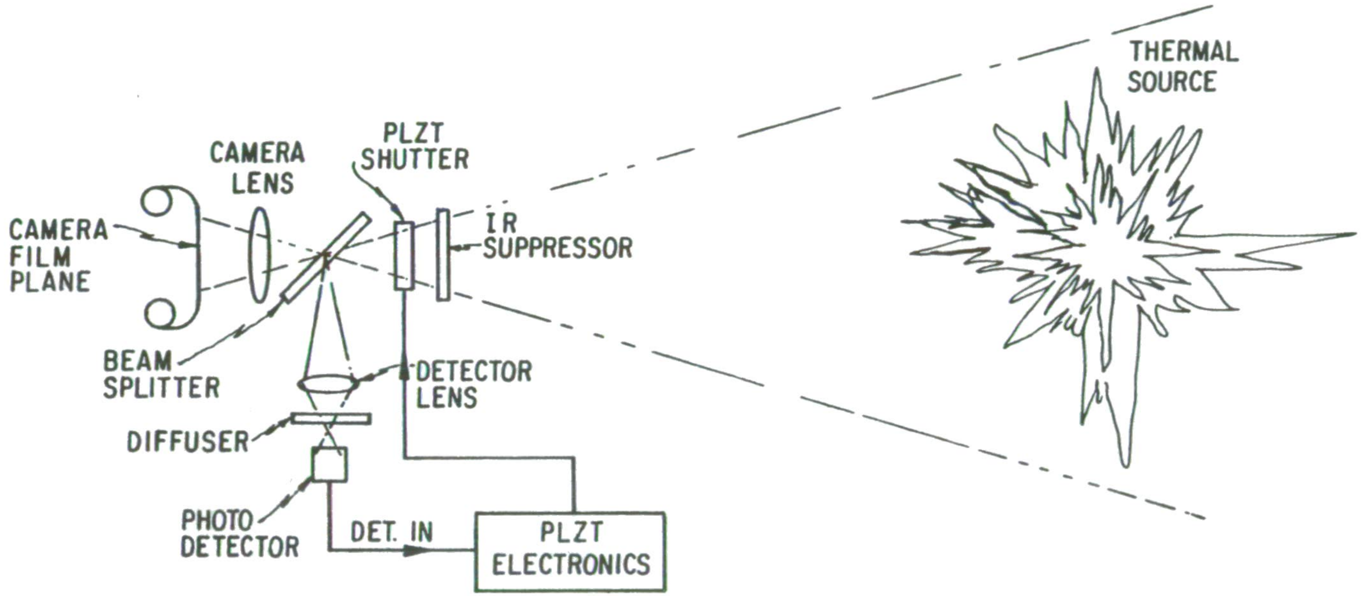


Figure 20. Future PLZT version.

SECTION 4

CONCLUSIONS

4.1 PROOF OF CONCEPT.

The PLZT photographic system proved successful in a MISTY PICTURE TRS experiment. This prototype system satisfactorily performed for the "proof of concept", that electronically controlled solid-state shutters could be servo looped satisfactorily into a high speed camera system, operating in high psi overpressures and thermal radiation environments.

4.1.1 Future Recommendations.

Recommendations for the future include modifying the optical system to increase the dynamic range to approximately 14 f-stops. Refinements and some redesign of the electronic control system would be required to take advantage of the increased range of the PLZT shutter by providing increased accuracies of the servo control loop through better signal/noise ratios. An additional benefit, of the new PLZT version, is that this concept would negate any hysteresis inherent in the shutter assembly, thereby providing added accuracy in controlling the radiation transmitted to the film plane during unknown dynamic light source events.

4.1.2 Conclusions.

Through this highly successfull test program, a new era in photo-instrumentation is on the horizon. It is evident that this system fully developed will, for the first time, provide a photographic system that could, by itself, fully document any anticipated TRS/HE source. This system, properly deployed, would substantially reduce operational

costs of the TRS documentation and provide superior data acquisition capability.

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